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Design and Development of Water-Injected Exhaust Manifold for Emission Control

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Abstract: The project focuses on reducing harmful automobile emissions through a water injection system integrated into the exhaust manifold. The proposed setup consists of a water tank, control valve, heat- resistant pipes, honeycomb pads, and nozzles. Water is sprayed onto the heated honeycomb pads, reducing exhaust gas temperature and converting toxic gases such as NOx, CO, and HC into less harmful forms. This simple, cost- effective modification shows significant emission reduction while maintaining system efficiency. Experimental results demonstrate notable decreases in exhaust temperature and emission concentration, making it an eco- friendly and retrofit-compatible solution for small engines.

Keywords: Emission Control, Exhaust Manifold, Water Injection, Honeycomb Pad, Pollution Reduction.

I. INTRODUCTION

The rapid increase in automobile usage has led to a significant rise in greenhouse gas emissions and air pollutants such as CO_2, NO_x, HC, and particulate matter (PM). These pollutants contribute to global warming and cause serious health issues, including respiratory and cardiovascular diseases. To address these concerns, researchers are exploring sustainable emission control technologies, among which water injection in exhaust manifolds has shown great potential. This method reduces exhaust gas temperature by spraying water into the exhaust stream, thereby lowering NO_x and PM emissions. Studies report up to 80% reduction in NO_x and 50% reduction in particulate matter using controlled water injection techniques.

In this project, a fluid-injected exhaust manifold was designed with four honeycomb pads and strategically placed nozzles that spray water onto the heated surfaces to break down toxic gases. Temperature sensors monitor inlet and outlet exhaust conditions, ensuring efficient operation and emission control. This system provides a simple, cost-effective, and adaptable solution for small engines, combining water injection and catalytic filtration to promote cleaner and more eco-friendly engine performance.

II. LITERATURE SURVEY

1. Patel et al. (2014) developed an aqua silencer system using water absorption and chemical reaction methods to minimize emissions.
2. Mahajan (2013) discussed air pollution from IC engines and emphasized the importance of chemical scrubbing.
3. Nour et al. (2016) analyzed water injection in exhaust manifolds and observed a decrease in NOx and particulate matter.

Mohapatra (2020) reviewed water injection systems, highlighting their cooling effects on exhaust gases.

III. EXISTING SYSTEM

The Conventional emission control systems in internal combustion engines rely mainly on catalytic converters and mufflers to reduce harmful gases. Catalytic converters promote oxidation and reduction reactions to convert

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Carbon Monoxide (CO) and Hydrocarbons (HC) into Carbon Dioxide (CO_2) and water vapor, while mufflers primarily reduce noise.

Although these systems have proven effective, their performance decreases at high exhaust temperatures. Excessive heat causes partial catalyst degradation and limits conversion efficiency, particularly for Nitrogen Oxides (NO_x). Furthermore, these systems do not control or reduce exhaust gas temperature, which is a key factor influencing NO_x formation.

In addition, conventional methods require expensive catalyst materials like platinum, palladium, and rhodium, which increase system cost. Maintenance is also difficult, and the efficiency deteriorates over time due to carbon deposition and catalyst poisoning.

Hence, while the existing system reduces emissions to some extent, it cannot maintain consistent performance over long operation periods and does not address the temperature-driven formation of NO_x gases. This limitation forms the basis for developing a water-injected exhaust manifold, which focuses on both temperature control and pollutant reduction.

IV. PROPOSED SYSTEM

The proposed system introduces a water injection mechanism integrated into the exhaust manifold to reduce both exhaust temperature and harmful gas emissions. This design aims to overcome the limitations of conventional catalytic converters by combining cooling, absorption, and catalytic reactions in a single unit.

The system consists of a water storage tank, control valve, heat-resistant pipe, and a modified exhaust manifold containing four honeycomb pads. A small quantity of water is injected through fine nozzles onto the heated honeycomb pads as the exhaust gases pass through the manifold. The injected water absorbs heat, vaporizes, and reacts with the exhaust gases, resulting in a reduction of NO_x, CO, and HC emissions. The honeycomb pads provide a large surface area for gas–liquid interaction, enhancing the absorption of pollutants and cooling efficiency. The process also reduces the velocity of exhaust gases, allowing more residence time for reactions to occur. This system requires minimal power, uses simple mechanical components, and can be easily retrofitted into existing vehicles. It is cost-effective, reliable, and suitable for small internal combustion engines used in two-wheelers, generators, and agricultural applications.

Fig. 1: Water-Injected Exhaust Manifold System

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V. PROPOSED BLOCK DIAGRAM

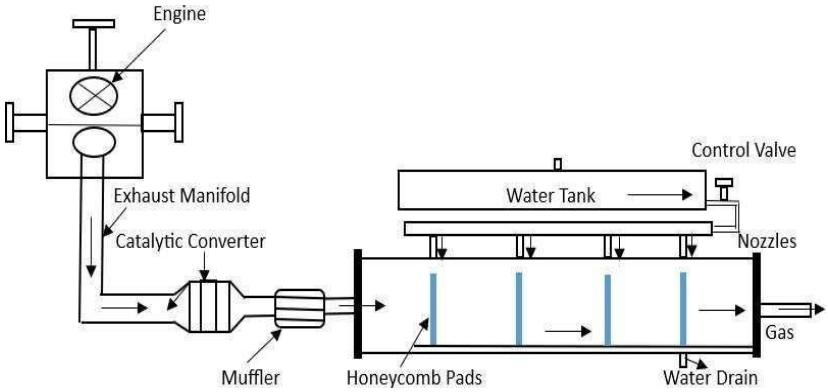

Fig. 2: Block Diagram of Water-Injected Exhaust Manifold System

This block diagram represents the working of the Water-Injected Exhaust Manifold System designed for emission control. During engine operation, high-temperature exhaust gases flow through the modified exhaust manifold. Inside the manifold, honeycomb pads are placed to increase the surface area for gas– liquid interaction. A controlled quantity of water from the storage tank is sprayed through heat-resistant nozzles onto these heated honeycomb pads.

When the water droplets strike the hot surface, they absorb heat and instantly convert into steam, thereby reducing the exhaust gas temperature. This cooling effect effectively suppresses the formation of Nitrogen Oxides (NO_x), which are primarily produced at elevated combustion temperatures.As the hot exhaust gases pass through the wetted honeycomb surfaces, unburned hydrocarbons (HC), Carbon Monoxide (CO), and other particulate matter come into contact with water molecules. These gaseous pollutants partially dissolve or condense into the water film present on the pads. The absorbed contaminants are then carried downward through a drain passage, where heavier or semi-solid residues such as carbon and methane-based compounds settle at the bottom as waste sludge.

This process results in the emission of cleaner exhaust gases with significantly reduced temperature and pollutant concentration. The collected waste water can later be filtered or replaced as part of regular maintenance.

ADVANTAGES:

1. Reduction in Harmful Emissions
2. Lower Exhaust Temperature
3. Simple and Cost-Effective Design
4. Particulate and Noise Reduction
5. Extended Catalyst Life & Eco-Friendly Operation

DISADVANTAGES:

1. Continuous Water Requirement
2. Risk of Corrosion
3. Slightly Higher Maintenance and Weight
4. Limited Use in Cold Conditions

APPLICATIONS:

1. Automobiles
2. Portable Generators & Marine Engines.
3. Agricultural and Industrial Engines

VI. RESULTS

The performance of the Water-Injected Exhaust Manifold System was evaluated by comparing the emission levels and exhaust temperatures before and after implementing the water injection setup. The experiment was carried out on a two-stroke petrol engine, and key emission parameters such as Carbon Monoxide (CO), Hydrocarbons (HC), and exhaust gas temperature were measured.

Without the water injection system, the engine produced higher emission levels due to incomplete combustion and high exhaust temperatures. After installing the proposed setup, a noticeable improvement in emission quality and temperature reduction was observed.

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The results indicated that:

- CO concentration reduced from 1.856% to 0.862%.
- HC concentration reduced from 1942 ppm to 1503 ppm.
- Exhaust gas temperature dropped from 47.3°C to 31.5°C.

This confirms that water injection significantly lowers the exhaust temperature by absorbing and converting part of the therm al energy into steam. The reduced temperature also minimizes the thermal formation of NO_x gases, while the honeycomb pads and water film help capture unburned hydrocarbons and soot particles.

Additionally, the outlet gas flow was found to be smoother and cooler, contributing to a noticeable reduction in e xhaust noise. The overall performance proved that the proposed system is efficient, low-cost, and environmentally sustainable, making it suitable for small and medium internal combustion engines.

TABLE 1 EMISSION TEST RESULTS

EMISSIONS	REGULATION	ACTUAL VALUES		
		1.BEFORE ARRANGE	2. WITHOUT WATER	3. WITH WATER
CO	3.5%VOL	1.856%VOL	1.637%VOL	0.862%VOL
HC	6000 PPM	1942 PPM	1883 PPM	1503 PPM
CO_2	10-13 PPM	3.56 PPM	3.34 PPM	4.23 PPM
O_2	30 PPM	18.02 PP	17.41 PPM	16.93 PPM

NOTE:

* **PPM**- Parts Per Million
* **VOL**- Volume

VII. CONCLUSION

The experimental system was successfully developed and tested to reduce harmful emissions from a two- stroke petrol engine. The setup involves injecting water directly onto hot exhaust gases through nozzles positioned over honeycomb pads inside the exhaust manifold. This process effectively lowers exhaust gas temperature, reduces Nitrogen Oxides (NO_x) formation, and helps settle particulate matter and unburned hydrocarbons.

The combination of honeycomb pads, control valve mechanism, and catalyst filters enhances gas–liquid interaction and pollutant absorption. As a result, the concentration of CO, HC, and NO_x significantly decreases, contributing to cleaner exhaust and environmental protection.

The system is simple, cost-effective, and easily adaptable for small engine applications such as two- wheelers, portable generators, and agricultural engines. Although it requires periodic water refilling and basic maintenance, the results demonstrate that the proposed design is an efficient and practical alternative to conventional emission control systems, ensuring reduced pollution and improved engine performance.

VIII. FUTURE SCOPE

The Water-Injected Exhaust Manifold System can be further developed to improve efficiency, automation, and long- term durability. Future enhancements may include:

1. Automatic water flow control using sensors to adjust injection rate based on exhaust temperature and engine load.
2. Integration with catalytic converters or EGR (Exhaust Gas Recirculation) systems for enhanced emission reduction.
3. Use of nano-coated or ceramic honeycomb materials to improve heat resistance and pollutant absorption capacity.
4. Application of the system to multi-cylinder and diesel engines for broader industrial and automotive use.

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5. Incorporation of wastewater filtration and recycling mechanisms to ensure clean operation and minimize maintenance.

With these advancements, the proposed system can evolve into a smart emission control technology, combining thermal management, chemical treatment, and self-regulating operation for sustainable environmental performance

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